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THE MP RESEARCH REACTOR FOR TESTING FUEL ELEMENTS AND MATERIALS

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General

The MP reactor is a multiloop research reactor chiefly designed for testing fuel elements and materials for new atomic power installations. In design it is the first prototype of channel-type swimming-pool reactors. The Kurchatov Institute of Atomic Energy began designing them in 1956. They successfully combine the advantages of channel-type pressurized water-cooled reactors with the facilities for experimental work typical of swimming-pool reactors.

The MP reactor has been constructed at the Kurchatov Institute to replace the РФТ reactor; it has been installed in the same building. The great experience in organising and conducting loop experiments gained during the long-term operation of the РФТ reactor was used in designing the MP reactor.

Work was organized so as to reduce the time interval between the shut-down of the РФТ reactor and the start-up of the new one. When the РФТ reactor was still in operation, additional basement rooms were built for a number of new loops. It was decided to install the equipment for the primary circuit and the cooling circuit of the MP reactor stacking in those basement rooms where physical instruments for experiments with the use of horizontal experimental beams of the РФТ reactor were mounted. Construction work and some of the assembly work was carried out before the РФТ reactor was shut down. After its shut-down on October 10, 1962, and its unloading and the dismantling of the primary circuit equipment and the loop assemblies, work was started on two pools: one for the MP reactor and the other for spent loop and fuel channels. The pools were built in that part of the РФТ reactor room under which there were basement premises.

While construction work was in progress, a separate building was used for the control assembling of the MP reactor core and the entire equipment to be installed in the reactor pool. Parallel with this, loop-circuit equipment was arranged in the old and new rooms for loop assemblies.

In the course of designing the MP reactor, the accepted solutions were to be checked experimentally. Experimental models of all non-standard units and parts were made and their effectiveness tested. On a hydraulic stand, losses of head in the complex units of fuel tubes and in some elements of the primary circuit were measured, vibrations of fuel tubes and simulated loop channels studied, and long-term tests of a fuel channel with a simulated fuel assembly were conducted with a view to studying the wear of contacting parts due to their vibration in the coolant stream. A special stand was used to check up on the characteristics of the systems intended for removing oxygen from the water in the primary circuit and that in the pool and their simultaneous saturation with hydrogen, to perfect water-gas ejectors and centrifugal separators and to study the intensity of interphase gaseous exchange. A reactor model (1/5) was made with all the equipment, mounted in the pool, and loop channels. This model made it possible to design simple devices for loading and removing, by means of an ordinary crane, fuel tubes and loop channels arranged in an inclined position. Models were also made to ensure the best geometry of the equipment in the rooms for loop assemblies. A uniflow U-shaped loop channel with non-standard fittings and a system for monitoring its hermeticity were tested on a full-size stand, in conditions of the design pressures, temperatures and flow rates of the coolant. The actuators for control and safety rods and mobile fuel assemblies were tested on a separate stand; hydraulic deceleration of safety rods during their fall was also experimentally adjusted.

The РФТ reactor was used to test the main parts of the new reactor core, fuel assemblies which in their design are similar to those of the MP reactor, and also ampoules with samples of beryllium and graphite-materials of which the core and reflector blocks in the new reactor are made. An ampoule with beryllium samples was fitted with an electric heater; the samples were irradiated in fast-neutron fluxes at considerable thermal stresses. Experiments with graphite were conducted to study the liberation of gases from pretreated graphite samples, under the action of radiation. The working principle of the channel-by-channel fuel-assembly hermeticity monitoring system, employed in the MP reactor and based on change in the coolant flow rate in this system according to the periodical law, was also checked.

On completing assembly work and adjustment, the MP reactor was brought to critical on December 28, 1963. Subsequently a thorough study of its physical and technical characteristics was made. The further adjustment of the equipment and instruments in the loop assemblies was continued simultaneously.

At the rated capacity of the reactor equal to 20,000 kw, the thermal-neutron flux in the central neutron trap, which is a sphere 100 mm in diameter, filled with water is 8×10^{14} n/cm^2.sec.

Design and Experimental Possibilities

The general view of the reactor and its separate parts and units are shown in Figs. 1-7 and 10-12. Its main technical characteristics are given in Table 1. The reactor core, fuel and loop channels, coolant distributing pipes and their headers are submerged into a pool. What is specific about the reactor design is the use of varying-with-height spacing between the channels. In the upper, middle and lower sections of the core this spacing is equal to 140,130 and 120 mm respectively. All this made it possible to provide sufficient spacing between the fuel and loop channel heads, with spaces between the fuel assemblies in the core made so that the reactor has good physical characteristics. The height of the reactor core is 1 m.

Original head seals have been designed for the reactor fuel channels made in the form of Field tubes. When the screw (Figs.11 and 12) is turned, the ball lock is locked, with subsequent compression of the three rubber rings. The fuel channels contain high-pressure water-cooled fuel assemblies. A fuel assembly (Figs.7 and 11) consists of five tubular fuel elements with three spacing lengthwise fins on the outer surface of each fuel element. Fins are formed when three-layer tubes are made by the extruding method in the process of hot pressing[x)]. The midlayer, which contains uranium, is equally thick between and under the fins. The spacing fins prevent the gaps in both the fuel assemblies and between them and the tubes of the fuel channels from being reduced when the fuel elements bend due to considerable thermal-neutron field gradients in a loop-type reactor.

x) The technological process of making such fuel elements was elaborated by R.S.Ambartsumyan, A.M.Glukhov, R.F.Smirnova et al.

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In the eight peripheral units of the core are installed channels with mobile fuel assemblies. These assemblies are inserted into the core from below upwards when the reactor is in operation. For the time the next assembly in turn is raised reactor power is considerably reduced. Aluminium-canned cadmium jackets are used to reduce heat release in the mobile fuel assemblies in the lower position under the core. Arranged inside the three-fin aluminium tubes, along the axis of the fixed fuel assemblies, are samples of materials for irradiation in intensive fast fluxes. Fuel assemblies with a smaller number of tubular fuel elements are used to irradiate large-size samples. The telescopic suspension stems for the mobile fuel assemblies, and the stems for the three-fin tubes, in the fuel tube heads, pass through packing glands.

Between the core fuel channels and in the first layer of the side reflector (Fig.5) are installed metallic beryllium blocks. They have through-holes into which beryllium plugs are inserted. In the second layer of the side reflector, graphite blocks in sealed jackets are used. All the blocks are 1,100 mm high. Fig.6 shows a photograph of graphite and beryllium blocks. In the I.5 mm gaps between the graphite and beryllium blocks and inside the beryllium blocks flows water from the reactor pool to cool these blocks. The holes in the beryllium blocks are used for installing channels with control and safety rods and for irradiating samples. The jackets of the graphite blocks are made of sheet aliminium 2 mm thick. Rows of dents on the facets form gaps between the graphite and the jacket. The greater amount of heat released in the graphite is transferred to the cooling water through the dents. Owing to this, the graphite blocks, which are nearest to the core, work at a temperature of about 300^{o}C, which is acceptable from the viewpoint of accumulating Wigner energy and changing the dimensions of the graphite blocks under the action of radiation. The gaps between the graphite and the jacket, and the pores in the graphite are filled with nitrogen at a pressure of $\sim$ 0.1 absolute atmosphere. Such initial pressure is used in connection with the chosen temperature conditions for the block operation and the possible liberation of gases from the graphite under the action of radiation. In the initial condition the facets of the jackets are slightly bowed. When the transverse dimensions of the graphite blocks are increased the bowing is reduced. The graphite is so oriented that its maximum radiation growth proceeds vertically. During the operation of the reactor it is possible to interchange the graphite blocks nearest to the core and those in the periphery.

The MP reactor core is designed for using uniflow U-shaped loop channels with branches, mounted away from the core, which serve to feed the heat-transfer agent. Thirteen such channels can be installed in the reactor at a time; nine of them are arranged in the core and four in the reflector. The maximum diameter for channels in the core is I50 mm , and for those in the reflector- 200 mm. The loading and unloading of a U-shaped loop channel is preceded by the withdrawal of some of the reactor stacking blocks close to the pipelines of this channel, which should then be put back. Groups of four beryllium blocks (Fig.I0) arranged around loop channels 4-2, 6-4, 4-6, 2-4 and 4-4 can be interchanged; the same applies to the blocks around loop channels 2-0, 6-0, 6-8 and 2-8, and also to the four symmetrical groups of six block each, such as blocks adjacent to channel 6-2 and the I30 mm beryllium plug in unit 7-2.

This plug can be replaced by a loop channel; in this case no loop channel should be installed in an adjacent unit, such, for instance, as unit 6-2.

By interchanging groups of blocks it is possible to install in the same core or reflector unit loop channels of various diametres, which increases the experimental possibilities of the reactor. All the units of the core not taken up by loop channels, except unit 4-4, can be loaded with fuel tubes. This is achieved by using replaceable support cups for fuel tubes, which are inserted in the loop channel support cups, and replaceable portions of pipelines to feed and remove the coolant. Ball locks are used in coupling fittings as in the case of fuel tube head seals. In the side reflector of the reactor, channels of various diametres are installed for irradiating materials and conducting other experiments.

The use of dismountable stacking for the core and the reflector makes it possible to introduce all the necessary changes when the design and dimensions of experimental installations are to be altered.

Mobile starting ionisation chambers are arranged in the periphery of the reactor stacking, while all the other chambers are outside the stacking body. All the ionisation chambers are located in water-filled channels and are hermetically sealed.

The actuators for the control and safety rods and those for the mobile fuel-assemblies are mounted on a traveling table. The design of the gripping device coupling the actuator with the stem of a mobile fuel assembly is shown in Fig.11; a similar coupling is also used for the control and safety rods; in the case of safety rods a system of hydraulic deceleration is used. The decelerating devices are installed in the guiding tubes of the actuator table, above water level in the pool, and they fall together with the rods.

For the reloading period all the control and safety rods and mobile fuel assemblies should be in the lower position. After these are lowered the actuator table is recoiled to the edge of the pool to free the space above the core.

The fuel-tube pipelines, intended to feed and remove the coolant, are coupled by means of two headers, on which control valves are mounted. The control stems of these valves come out through the holes in the upper shield plates of the reactor. The use of a ball lock in such valves makes it possible to effect remote withdrawal of their parts for replacement or repair. At the outlet of each fuel tube, the pressure, flow rate and temperature of the coolant are measured and its removal to the fuel-assembly hermeticity monitoring system effected.

The employment of a ring header in the stacking cooling ciruit made it possible to organize water circulation in such a manner that the liquid is fed to the upper part of the pool after the short-lived radioactive admixtures contained in it have disintegrated to a considerable extent.

The reactor pool and the storage pool are linked by means of a sluice (Fig.4). The pools and the sluice have a stainless steel facing. Spent fuel assemblies are removed from the reactor and transported to the storage pool together with their working or loop channels. More than that, the lower parts of the channels, where fuel assemblies are arranged, are always kept in water. The storage pool has special places for channels with fuel assemblies, extracted from the reactor. Moreover, it has a gamma-irradiator, in which spent fuel assemblies are used, and a separate tank with equipment for underwater cutting of channels of all types. Spent fuel assemblies do not touch the water of the storage pool; after a proper hold-up they are extracted from the channels and transferred to a hot cave. Owing to the gamma-irradiator high power, which reaches several million curies, its chamber is mounted at some distance from the walls and bottom of the pool and is washed with water. Besides, cooling coils are laid in those parts of the concrete block which are close to the irradiator chamber. Spent fuel assemblies with their channels are loaded into the chamber from above through the guiding tubes. Before loading, an aluminium shield jacket closely fitting both the channel and the guiding tube is put on the upper part of each channel. Channels together with their shield jackets are secured on suspensions through which water cooling the fuel assemblies is fed and removed. Objects to be irradiated are fed into the chamber on a mobile table with a cantilever. At this moment all the fuel assemblies are removed from the irradiator chamber and are found in the guiding tubes. The irradiator is so designed that it makes possible the most rational disposition of fuel assemblies not only around but also inside the objects to be irradiated, if their shape so permits. Channels with fuel assemblies can also be installed outside the irradiation chamber, close to its walls. Objects for irradiation can have the most varied dimensions.

The Flow Diagram

The diagram given in Fig. 13 comprises the following technological systems of the reactor: a fuel-assembly cooling circuit (the first circuit), a stacking cooling circuit, systems for removing oxygen from the water in the first circuit and in the pool and its saturation with hydrogen, systems for water purification with the aid of mechanical and ion-exchange filters, a first-circuit evacuating system and a channel-bychannel fuel-assembly hermeticity monitoring system.

In the first circuit of the reactor are employed packless pumps. All the fittings of this circuit, with the exception of some large dampers, are bellows-sealed. In the circuit, two main and two emergency pumps work simultaneously. When any one of these pumps is out of order, the reactor is shut down. Pressure head in the emergency pumps is much lower than that in the main ones. In case of simultaneous work, the non-return valves of the emergency pumps are shut. In these conditions the emergency pumps operate at low capacity, discharging water into a suction header. When the main pumps are cut off, the non-return valves of the emergency pumps open and the major portion of the coolant, pumped over by the emergency pumps now operating at full capacity, is fed into the reactor. In the reactor stacking cooling circuit, three main and one emergency pump work simultaneously.

The systems for removing oxygen from the water and saturating it with hydrogen serve to combat coolant medium radiolysis and core and circuit material corrosion. The main equipment of these systems consists of water-gas ejectors, centrifugal separators, draining facilities, platinum catalysts and induction electric heaters. The ejectors are intended not only for effecting gaseous mixture circulation; moreover, in conjunction with the separators they ensure the removal of oxygen from the water and its saturation with hydrogen. They made it possible to abandon the use of gas blowers and jet degasifiers.[x)]

Channel-by-channel fuel-assembly hermeticity monitoring is based on the detection of the gamma-activity of uranium fission short-lived fragments which get into the water from a failed fuel assembly. The background gamma-activity of long-lived radioactive nuclei is cancelled by changing the water flow rate in the channel-by-channel monitoring system according to the periodical law. For this purpose a valve with electric drive is installed on the line after the data units of this system.[xx)] Provision is made for the installation of additional data units on the lines following from the channels. This makes it possible to study the efficacy of other methods for fuel-assembly hermeticity monitoring.

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x) The systems were elaborated by Y.G. Nikolayev and A.A.Chernyatsov.

xx) The monitoring method was proposed by Y.G.Nikolayev and L.A.Goncharov.

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Specific Features of Reactor Physics

In loop swimming-pool reactors of the channel-type, metallic beryllium is the best material for filling interchannel space in the core.

If inter-channel space is filled with light water, then for a reactor to have satisfactory physical characteristics very little space between the channels would be required. Such a reactor would be rather complex in design because of a great number of channels necessary to create a large core, and also because several fuel tubes would have to be removed to provide room for a large diameter loop channel. Moreover, owing to its short diffusion length, water is not the best material for filling the space around the loop channel, which strongly disturbs the thermal-neutron field. When loop channels are surounded with ordinary water, thermal flux dips are particularly great. Also for this reason it is not profitable to have an ordinary water reflector in a loop-type reactor.

The employment of metallic beryllium blocks for the core in conjunction with varying-with-height spacing between the channels, and the use of graphite blocks in the side reflector made it possible to create a comparatively simple multiloop reactor which has good physical characteristics and great experimental possibilities. The reactor would have still better physical characteristics if there were no water at all in the core and reflector stacking, as was the case with the РФТ reactor.

The mean content of water in the MP reactor core is 20 per cent. One fourth of it is between the fuel tubes. It accounts for approximately 75 per cent of the mean moderating power of all the materials in the core. In a unit of the MP reactor, thermal flux distribution is rather uneven, for over 40 per cent of the slowing-down neutrons are thermalised outside the fuel channel. Fig.8a represents a calculated curve of radial thermal flux distribution. This distribution has been obtained as a result of the numerical solution, by the characteristics method of a one-velocity kinetic neutron transfer equation in cylindrical geometry.[x)]

Figs.8b and 8c show radial thermal and epithermal flux distribution in the core and the reflector calculated in two-group approximation, and thermal flux height distribution in the reactor. Height distribution differs from the ordinary one because of the varying spacing between the channels.

The critical mass of the MP reactor turned out to be equal to approximately 2 kg of uranium-235. This value was obtained in conditions in which beryllium plugs were inserted in all the core units adjacent to the central units taken up by fuel-assembly channels. When the physical characteristics of the reactor were studied, experiments with water-filled central neutron traps of various configuration were in particular conducted. A spherical trap 100 mm in diameter, with beryllium plugs arranged over and under it, proved to be the best. A thermal flux of 8×10^{14} $n/cm^2 sec$. is ensured at a power of 2,000 kw obtained from each one of the four fuel assemblies nearest to such a trap.

Table II shows the main physical characteristics of the reactor. The first ten values are given for the averaged nuclear composition of the core and the reflectors. The value of the infinite multiplication factor, equal to 1.61, does not take into account the effects connected with $(n, 2n)$ and (n, α) beryllium reactions. Calculations show that at the initial stage K_∞ will be 4 to 7 per cent higher, depending on

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x Calculations were made according to the programme drawn up by V.I.Lebedev and Y.A.Grigoryeva.

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which data published on (n,2n) reaction cross-sections are used. Most of this positive effect disappears towards the end of the first year of operation due to the beryllium being poisoned with $_3Li^6$ nuclei formed as a result of the n,α reaction. Subsequently, as $_2He^3$ nuclei accumulate in the beryllium, K_∞ will very gradually be reduced.

Owing to the γ,n beryllium reaction, the MP reactor core is a powerful source of photoneutrons. This makes it possible to control, with comparative ease, reactivity changes in a subcritical state, during reloading operations.

In order to avoid substantial changes in the capacity of the loop channels during the reactor operating cycle, provision is made for the following sequence of movements for the control rods and the mobile fuel assemblies. As the reactor is poisoned the shim rods are removed in the first place (see Fig.IO). Then, as the fuel burns up, the mobile fuel assemblies are introduced into the core one by one; and the four peripheral shim rods are again lowered into the core. The operational reactivity margin (shown in Table II) of the reactor at the end of its working cycle is ensured by these four rods.

The existence of a considerable operational reactivity margin makes it possible to bring the reactor to power after forced or planned shut-downs for less than an hour.

Experimental Loop Assemblies of the Reactor

The MP reactor is equipped with a number of experimental loop assemblies with various coolants. These assemblies are used to test new experimental fuel elements and construction materials for various power reactors being designed or under construction.

Moreover, they are used for studying the behaviour of coolants in pile radiation conditions and testing the coolant-purification system, as well as for other experimental purposes.

The brief characteristics of the loops are given in the folloeing table.

Loop	Coolant	Heat power (kw)	Maximum pressure (kg/cm^2)	Coolant maximum tempera-ture (°C)	Coolanat flow rate (t/hr)	Number of experimental channels
Pressurised boiling water-cooled loop	Water-steam emulsion	2500	200	365	300	3
Pressurised boiling water-cooled loop with carbon steel equipment	-"-	I500	200	365	30	3
Pressurised water-cooled loop	Water	I500	200	350	30	3
Organic-coolant loop	Organic liquids	I000	I00	400	30	2
Helium-cooled loop	Helium	I000	I00	850	1.8	1
CO_2-cooled loop	Carbon dioxide	500	60	550	5.0	2

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The parameters of the MP reactor experimental loops make it possible to test full-size fuel assemblies for reactors designed. When experimental loops were designed and constructed, special attention was paid to the reliability of their primary circuits and their technological equipment and also to their hermeticity and trouble-free performance in long-term operation at very high parameters.

a) Experimental Loops With Heat-Transfer Fluids

The MP reactor loops with pressurised water and organic liquids (a pressurised boiling water-cooled loop, a pressurised boiling water-cooled loop with carbon steel equipment, a pressurised water-cooléd loop, and an organic-coolant loop)have similar diagrams. They operate at high pressures and temperatures, are equipped with packless circulation pumps and bellows-sealed fittings and have similar safety shut-down cooling systems. The equipment of the pressurised boiling water-cooled loop and the pressurised boiling water-cooled loop with carbon steel arrangements ensures the possibility for conducting experiments with water bulk boiling in the reactor experimental channels at a steam content of 7 to IO per cent by weight. As distinct from other loops, the main units of a pressurised boiling water-cooled loop with carbon steel equipment (heat exchangers, separators, a condenser and a regenerator) are made of pearlite steel. This assembly is used to study the possibility of employing carbon-steel equipment in the primary circuit of a power reactor, to investigate carbon steels for corrosion in water and steam at high parameters, to try various methods for chemical pretreatment of the circuit, and to study methods for removing corrosion products and fission fragments from the coolant and the surfaces with which it comes into contact.

An organic-coolant loop is used for ascertaining optimal operating conditions for organic coolants, and adjusting systems for removing polymerisation products from them and recombining polymers into their initial product. The loop is also used to investigate changes in the conditions of heat transfer on fuel-assembly surfaces. Pressure in the loop circuits is maintained either by the steam or gas blankets of volume compensators of by make-up pumps. The coolant and scrub solutions are removed from the water-cooled loop circuits into sedimentation tanks and the purification system through a special pressure hermetic sewerage system, without contaminating premises for loop assemblies with radioactive products.

Reliability of the automatic safety shut-down cooling systems is of special importance for powerful experimental loops. On loops with liquid coolants such systems are installed according to one principle. When the loop assembly operates normally, one of the two main and one of the two reserve pumps are cut in. In case the working pump is out of order and cut off, the reactor safety system is switched on and the reserve pump is automatically cut in. In case the two main pumps are out of order or the two different power systems, to which the main pumps are connected, are simultaneously de-energised, the reactor is shut down and the second emergency pump is cut in. The emergency pumps, connected to the failureproof power supply system, ensure coolant circulation in the loop and the removal of afterheat in the experimental channels. In case the emergency pumps are cut of commission, the coolant can be directly fed into the channels by means of make-up pumps.

Water used in experimental loops as a coolant is specially pretreated. A boiler installation is employed to distill it twice. Then the distillate is fed into an evaporator where a part of it is turned into steam which together with the air solved in the water is "dumped" into a condenser. The distillate thus degassed is fed into a cooler and then into a common reserve tank where it is kept under slight helium overpressure. From this tank the water is delivered into the water-cooled loop make-up

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vessels and also for reactor primary circuit make-up. The distillate fed into these vessels first goes through appropriate ion-exchange filters. It is thus possible to prepare water with the necessary salt-content and "$_p$H" parameters for each loop. Besides, provision is made for adding various chemicals directly into any loop make-up vessels.

Each water-cooled loop is equipped with an independent system of mechanical and ion-exchange filters intended to rid coolant medium of corrosion products and fission fragments.

b) Experimental Loops with Gas Coolants

Helium-cooled loop and CO_2-cooled loop are intended for complex fuel element tests and for researches of coolants for high-temperature gas-cooled power reactors. These installations can be used for simulating tense operating conditions for experimental fuel elements: thermal loads of 1.0×10^6 kilocal /m^{2}hr and 5×10^6 kilocal./m^{2}hr , and surface temperatures of 600°C and 1800°C in CO_2-cooled and helium-cooled loop assemblies respectively.

In the section between the channel and the regenerator, the helium-cooled loop has complex paths for helium circulation at a temperature of up to 850°C and under a pressure of 100 kg/cm^2. The pressure tube is made of stainless steel; its temperature does not exceed 500°C. Inserted into it are three thin-walled tubes made of heat-resistant steel. The inner tube serves for gas circulation, while the other two play the role of thermal shields. The inner tubes are in an unloaded state and can be telescopically compensated for thermal expansion.

Gas-cooled loops are fitted with appropriate systems of filters (mechanical, ceramic and cloth) for coolant purification during their work. Moreover, a liquid-nitrogen-cooled block of carbon adsorbers is mounted on the helium-cooled loop for removing gaseous fission products.

The gas-cooled loop vacuum equipment is intended to preevacuate the main circuits of the assembly before they are filled with a coolant. This equipment is also used to evacuate the heavily contaminated coolant into a gaspurification system. This system, which also comprises the gas lines of the liquid-coolant loops, consists of gasholders, various filters, high-pressure vessels for holding-up the contaminated coolant, and appropriate compressor equipment.

c) Experimental Channels of the Loops and Their Hermeticity Monitoring System

The arrangement of one of the uniflow U-shaped loop channels of the MP reactor is shown in Fig.9. Such loops are rather complex in design. However, they have a number of advantages. For testing experimental fuel assemblies similar in size, a uniflow loop channel, as distinct from Field tubes, is made of smaller-diameter and thinner pipe. In high-pressure work, this leads to a roughly 1.5 times increase in the thermal flux, which considerably widens the experimental possibilities of the reactor. The loop channels are almost completely submerged into the reactor pool. They have hermetic jackets, separating the high-pressure and high-temperature tubes from the water in the pool. The main tubes in the loop channels also have jackets to isolate them from the cold water in the reactor pool. The jackets within the limits of the core are made of aluminium alloy. The air-filled space between the main tubes and the jackets is evacuated and linked with the channel hermeticity monitoring system which gives warning and emergency signals. When vacuum drops to a certain level and in case the loop-channel cooling system fails, the reactor is shut down and the vacuum cavities are simultaneously filled with helium. These measures make loop tests in the reactor completely safe.

Special fittings, designed to connect the loop channels with their circuits and the hermeticity monitoring system, are arranged in cellers adjacent to the pool edge. The dismountable barriers and ceilings of the cellers separate them from one another and from the adjacent rooms. They are ventilated so as to maintain the maximum air rarefaction in them as compared with the adjoining premises. The cellers are connected to the special sewerage system. In case the main tubes of channel head seals are uncanned, the escaping coolant gets into a celler. Air samples are taken from each celler and tested for radioactive admixtures. Air humidity in the water-cooled loop cellers is continuously checked. A loop channel can be disconnected from its circuit through the holes in the shield plates, without the need to take them off. The contaminated surfaces inside the celler can be washed through the same holes. The fittings arranged in the cellers make it possible to seal the ends of the tubes in a loop channel and its circuit after their disconnection.

The use of such cellers helps to avoid the spread of radioactive contaminants in the reactor room.

Special demands are made on loop channels because this part of the experimental assembly operates in very hard conditions (maximum temperatures, maximum mechanical stresses, radiation effects). That is why manufactured loop channels are subjected to severe tests, while the time for their service in the reactor is limited.

Here are those who played an important part in the design of the MP reactor: V.I.Bespalov, L.A.Goncharov, G.A.Dyomin, N.A.Karasev, V.F.Karachinsky, A.B.Kruglov, I.M.Novikov, N.F.Russkov, A.V.Taliyev, V.K.Fishevsky, I.I.Shalin, B.A. Yatsenko and others from among the operating personnel of the РФТ reactor.

<u>Table I</u>

MP Reactor Technical Characteristics

I. Maximum capacities:	
of the reactor (without the capacities of the loops)	20,000 kw
of a fuel assembly	2,000 kw
2. Maximum coolant flow rates:	
in the primary circuit	600 t/hr
in the stacking cooling circuit	I000 t/hr
through the ejector nozzles in each circuit	50 t/hr
in a fuel channel	25 t/hr
3. Coolant pressures in the primary circuit:	
maximum	2I kg/cm^2
at the core outlet	I0 kg/cm^2
in the volume compensator	8 kg/cm^2
4. Cooling water temperatures:	
at the channel inlet	40°C
at the outlet of a channel with maximum heat release	II0°C
at the stacking inlet	45°C

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5. Data on the fuel assemblies and their operating conditions at a power of 2000 kw:

length of the active part . . . . 1000 mm
heat-exchange surface . . . . 1.4 m^2
heat-release layer thickness . . . . 0.5 mm
can thickness . . . . 1 mm
uranium-235 content . . . . 350 gr
maximum thermal flux . . . . $2x10^6$ kilocal /m^2hr
coolant velocity . . . . 6.5 m/sec
maximum temperature of the wall under the fin ..... 160°C
maximum temperature of the wall between the fins ..... 140°C
margin prior to boiling . . . . 20°C

6. Materials:

fuel . . . . 90 per cent enriched uranium
fuel element cores . . . . uranium—aluminium alloy
fuel element cans . . . . aluminium alloy
fuel channels and control and safety-rod holes . .. aluminium alloy
control and safety rods . . . . Al-clad boral
stacking body with the support grid,
protective plate . . . . aluminium alloy
support structures in the pool,
headers, fittings, cooling circuit
pupelines, parts of the table for actuators,
pool facing . . . . stainless steel

7. Core and side reflector average volumetric composition:

core	beryllium	0.658
	water	0.201
	aluminium	0.139
	uranium	0.00123
first reflecting layer	beryllium	0.97
	water	0.03
second reflecting layer	graphite	0.888
	water	0.025
	aluminium	0.059
	gas gaps	0.028

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Table II

MP Reactor Physical Characteristics

Thermal utilization factor	0.788
Resonance capture escape probability	0.987
Infinite medium multiplication factor	1.6I x)
Square diffusion length, cm^2:	
core	I2
side reflector 1st layer	300
side reflector 2nd layer	580
Square length of moderation, cm^2:	
core	6I.5
side reflector 1st layer	78.5
side reflector 2nd layer	270
Reflector savings, cm :	
side reflector	I8
end reflectors	8 and 9
Full reactivity margin with 37 fuel assemblies,%	27 xx)
Reactivity margin distribution,%	
steady-state xenon poisoning	4
burn-up and samarium poisoning	I4
loop and other experiments	I0
operational reactivity margin	1.5
Effectiveness of the control and safety system,%:	
safety rods (6 units)	4
shim rods (9 units)	4.5
mobile fuel assemblies (8 units)	3.5
Maximum specific power:	
volume, kw/l	I60
fuel, kw per 1 kg of uranium-235	9500
Maximum thermal fluxes (at $T_{n.g.} = 293^{o}K$) n/cm^2sec:	
in the central spherical trap	$8xIO^{I4}$
in the uranium	$2.4xIO^{I4}$
Maximum fast fuel-assembly axial flux ($E \geqslant 0.5$ Mev) . . .	$I.5xIO^{I4}$
Burn-up of uranium-235 in fuel assemblies,%	
maximum	40
average	30
Operating charge, kg.of uranium-235	7
Maximum number of fuel assemblies in the core during the operating cycle	28
Duration of the operating cycle, days	2I
Number of operating cycles per charge (28 fuel assemblies)	5

x) Without taking into account n,2n, γ,n and n,α beryllium reactions.

xx) Reactivity balance was calculated according to the formula: $1 - \rho = \prod_i (1 - \rho)$

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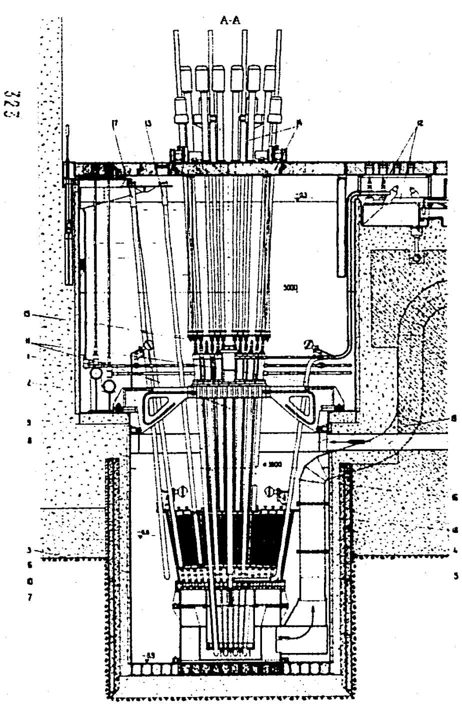

Fig.2. Part of the reactor pool room; table for the actuators of control and safety rods and mobile fuel assemblies is seen.

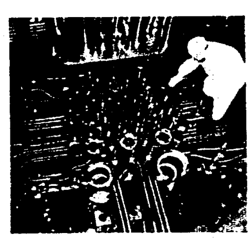

Fig.3. Top view of the reactor. Loop channels are not installed.

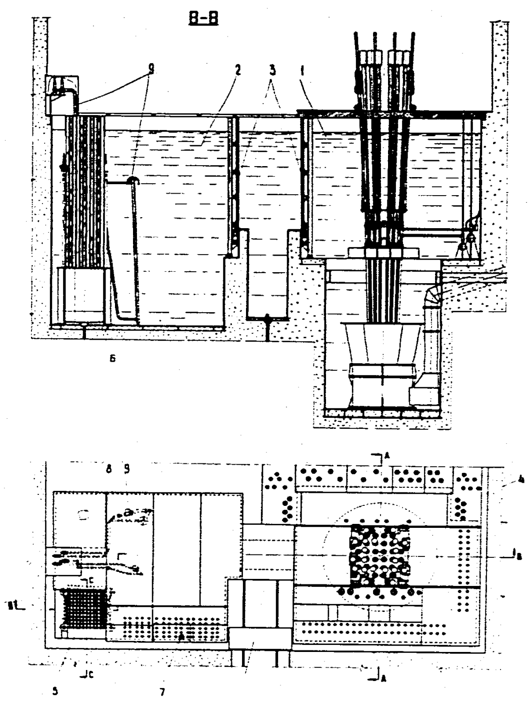

Fig.1. Reactor cross-section.
1. Primary circuit headers with fittings; 2. support plate of loop and fuel channel guiding cups; 3. core vessel body with support grid; 4. beryllium blocks; 5. aluminium-canned graphite blocks; 6. protective plate; 7. support structure; 8. fuel channel with fixed fuel assembly; 9. fuel channel with mobile fuel assembly; 10. aluminium-canned cadmium screen; 11. central uniflow U-shaped loop channel; 12. junction between loop channel and its circuit; 13. sample hole; 14. table for the actuators of the control and safety rods and mobile fuel assemblies; 15. junctions between the actuators and the control and safety rods and mobile fuel assembly stems; 16. channel with control and safety system rod; 17. ionisation chamber channels; 18. pool circuit pipeline (shown conventionally); 19. pool circuit header.

Fig.4. Top view and longitudinal section of the reactor pool and the storage pool.
1. Reactor pool; 2. storage pool; 3. sluice gate; 4. shield plates over the junctions between loop channels and loop circuits; 5. gamma-irradiator tube plate; 6. gamma-irradiator chamber; 7. fuel channel with fuel assembly, withdrawn from the reactor; 8. tank with equipment for underwater cutting of channels of all types; 9. loop channel with fuel assembly, removed from the reactor.

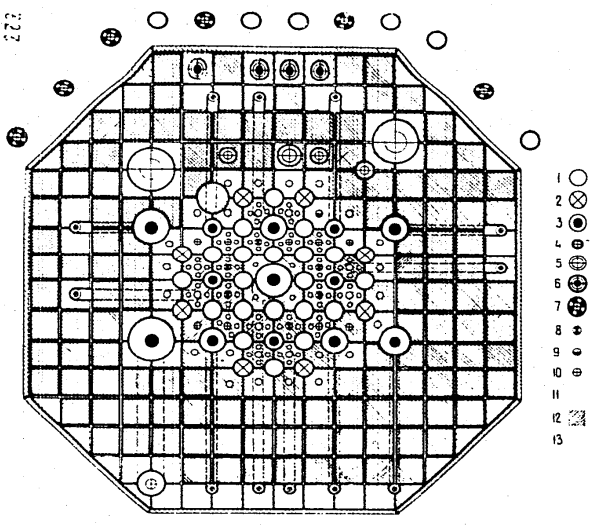

Fig.5. Core and reflector horizontal section.
1. Fuel channel with fixed fuel assembly; 2. fuel channel with mobile fuel assenbigy; 3. uniflow U-shaped loop channel; 4. loop channel pipeline to feed coolant; 5. sample hole; 6. mobile ionisation chamber channel; 7. fixed ionisation chamber channel; 8. safety rod; 9. automatic regulation rod; 10. shim rod; 11. beryllium blocks; 12. aluminium-canned graphite blocks; 13. aluminium blocks.

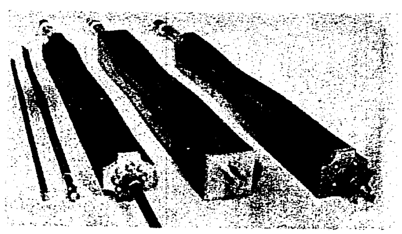

Fig.6. Aluminium-canned graphile block, beryllium blocks and plugs. A channel with a control and safety system rod is inserted into one of the blocks.

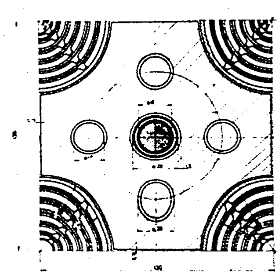

Fig.7. Core unit; a channel with a control and safety system rod is installed in the central hole of a beryllium block.

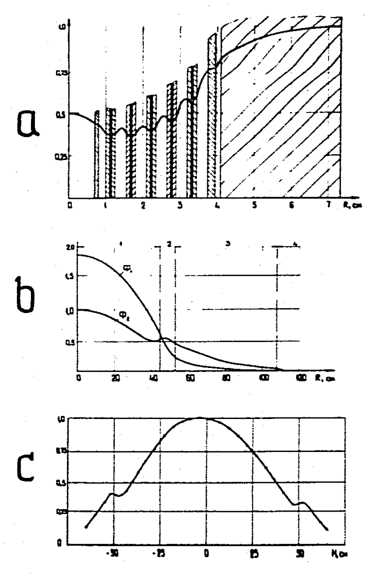

Fig.8. (a and c). Unit radial and reactor height relative thermal distribution; b. reactor radial epithermal (Φ_1) and thermal (Φ_2) relative distribution; 1. core; 2 and 3. first and second reflecting layers; 4. water.

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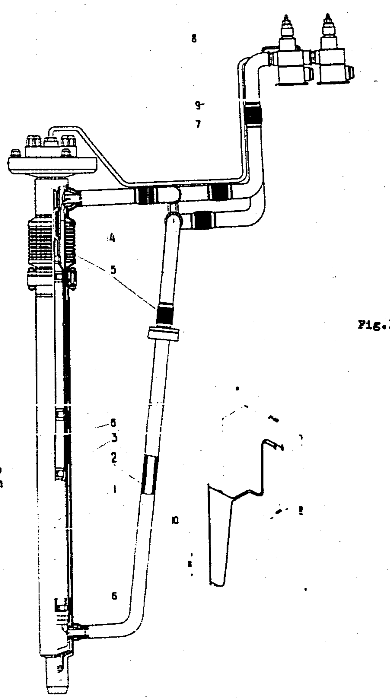

Fig.9. Loop channel general view and diagram.
1. Fuel assembly; 2. channel main tubes; 3. aluminium-alloy insulating jackets; 4. stainless steel jackets; 5. temperature expansion compensators; 6. thermocouple; 7. tube for leading out the thermocouple lines and for monitoring channel head seal hermeticity; 8. line for evacuating the inter-tube space and filling it with helium in case of emergency; 9. fittings for connection with loop circuit; 10. position of the core centre.

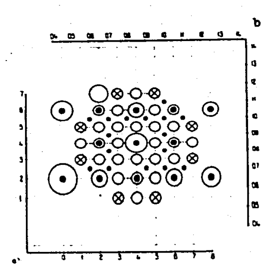

Fig.10. Diagram showing the disposition of fuel and loop channels and control and safety rods (for symbols see Fig.5).
a. Co-ordinate scales of fuel and loop channels; b. co-ordinate scales of the stacking blocks of the core and the reflector.
The first digits of the channel or block number are determined according to vertical scales.

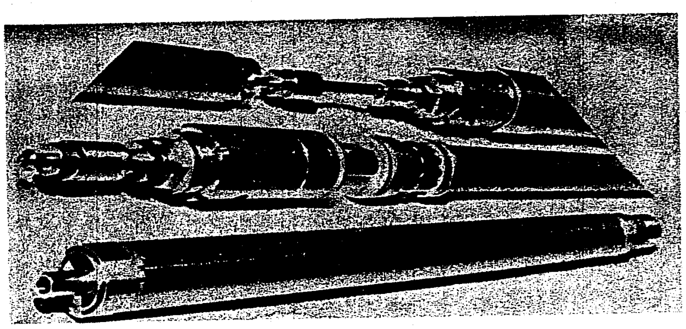

Fig.11. Five-tube fuel assembly with spacing ribs; parts of fuel channels with fixed and mobile fuel assemblies. The head of the channel with a fixed fuel assembly projects from the support cup; stem and its head grip are seen.

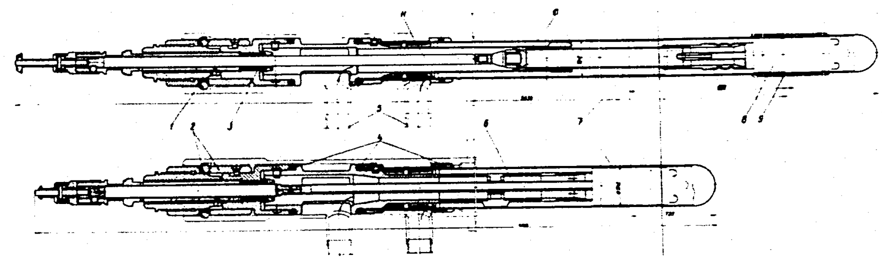

Fig.12. Fuel channels with mobile and fixed fuel assemblies.
1. Support cup; 2. ball lock; 3. packing gland; 4. ring rubber seals; 5. cooling water feed and removal; 6. ribbed tube; 7. fuel assembly in working position; 8. mobile fuel assembly in the lower position; 9. aluminium-canned cadmium screen; 10. telescopic suspension; 11. stem.

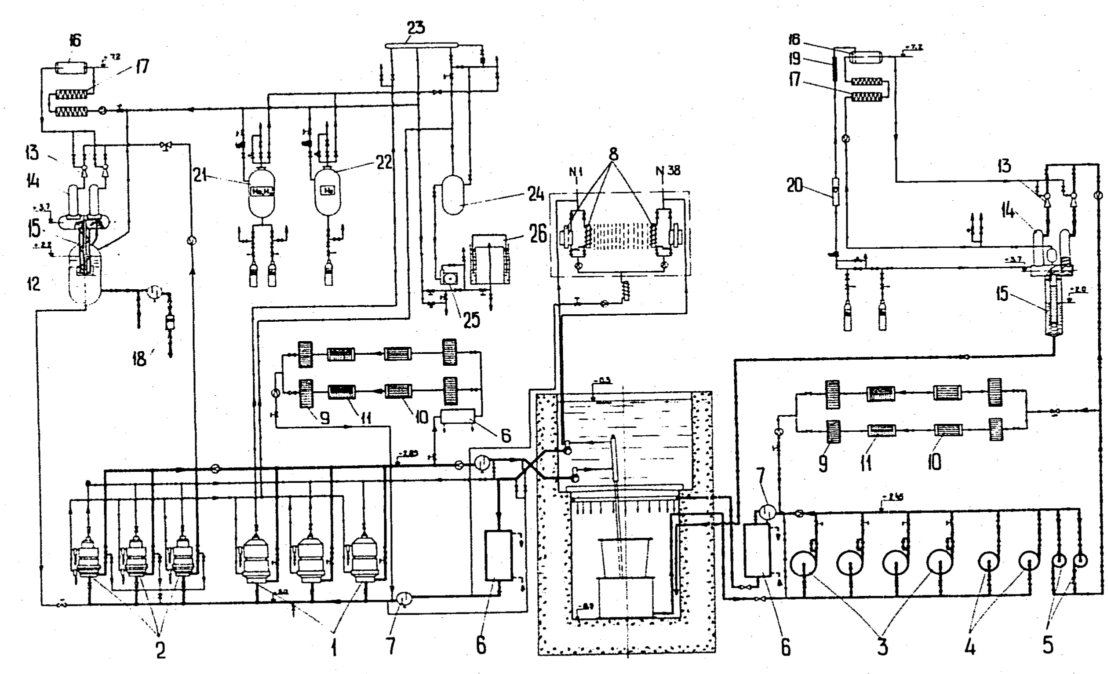

Fig.13. Flow diagram.

1 and 2. Main and emergency packless pumps of the primary circuit; 3 and 4. main and emergency pumps of the stacking-cooling circuit; 5. pumps of the systems for removing mechanical and ion admixtures and dissolved oxygen from the water; 6. heat exchanger; 7. meshy filter; 8. data units of the channel-by-channel fuel-assembly hermeticity monitoring system; 9. cloth filter; 10. cation filter; 11. filter with a mixture of cation-exchange and anion-exchange resin; 12. volume compensator; 13. water-gas ejector; 14. separator; 15. draining facility; 16. platinum catalyst; 17. induction heater; 18. make-up pump; 19. flow-limiting device in the hydrogen-feeding line; 20. ratemeter; 21. vessel with a helium-hydrogen mixture; 22. vessel with helium; 23. collector of the vacuum lines; 24. intermediate vessel; 25. vacuum pump; 26. gas holder.